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METEOROLOGY & AIR QUALITY

Los Alamos

National Laboratory

Risk Reduction and Environmental Stewardship Division

Meteorology and Air Quality Group (MAQ)

Quality Assurance Project Plan

for the

Meteorology Monitoring Project

Prepared by: Jeremy Rishel, MAQ Meteorology	Date: 8/20/03
Reviewed by: Darrell Holt, Meteorology Team Leader	Date: 8/20/03
Approved by: Terry Morgan, QA Officer	Date: 8/20/03
Approved by: Jean Dewart, MAQ Group Leader	Date: 8/21/03

General Information

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Appendixes

This plan has the following appendixes:

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History of Revision

The following table lists the revisions, dates, and changes to this document.

Revision	Date	Description of Changes
0	7/7/86	New document.
1	-	Document not available.
2	12/6/89	Revised and updated.
3	-	Document not available.
4	6/19/92	Revised and updated.
5	2/24/93	Revised and updated.
6	6/4/98	Extensively revised, updated, and reformatted.
7	9/13/99	Technical updates, reformatted.
8	8/19/03	Revised and updated.

Definition

This quality assurance project plan (QAPP) describes how meteorological monitoring is conducted at Los Alamos National Laboratory (LANL) by the Meteorology and Air Quality Group (MAQ).

Guidelines

This QAPP uses the format recommended in Department of Energy (DOE) Order 414.1A, but elements of the data quality objective process (EPA 1994a) from the Environmental Protection Agency (EPA) QA/R-5 document (EPA 1994b) are also included. The document is tiered with respect to the MAQ Quality Management Plan (MAQ-QMP) and the program's implementing procedures. Taken together, these documents formally describe the program's mission, organizational structure, roles and responsibilities, work processes, and the way quality is assured.

This QAPP is a controlled document. It is reviewed annually and revised if necessary, and it is distributed in accordance with the MAQ document control program (MAQ-030, "Document Distribution").

General Information, continued

Revising and distributing this plan

The group leader and a chosen reviewer will approve all revisions to this plan.

This plan will be distributed under the group document control program in accordance with procedure MAQ-030.

Section 1

Program Description

Requirements

Applicable DOE orders

The main DOE orders and guidance documents that describe the rationale and requirements for meteorological monitoring programs at DOE sites include:

- DOE Order 450.1 (DOE 2003), which requires the establishment of an environmental monitoring program (EMP) at DOE facilities to

  - assure compliance with applicable regulations,
  - confirm adherence to DOE environmental protection policies, and
  - support environmental management decisions;

- DOE/EH-0173T (DOE 1991), which describes the elements of an acceptable effluent monitoring and environmental surveillance program at DOE sites, including meeting the data needs for impact assessment, environmental surveillance, and emergency response; and

- DOE Order 151.1A (DOE 2000), which provides the framework for development, coordination, control, and direction of all emergency planning, preparedness, readiness assurance, response, and recovery for the DOE Emergency Management System; the role meteorology plays in the consequence assessment process is covered in Volume IV, Program Elements (2).

Objectives

Introduction

The program has two main objectives: (1) maintain a plume modeling capability for the Laboratory's Emergency Management Program, and (2) provide general meteorological support for Laboratory operations, environmental studies, and regulatory compliance activities.

Plume modeling

The plume modeling objective involves the calculation of potential radiological or toxicological hazards in the event of an accidental or sabotage-related release of hazardous materials to the atmosphere. These calculations require meteorological conditions, source and release information, and geographical data to estimate plume location and the associated ground-level air concentrations. Performing these calculations is part of the consequence assessment process in responding to an emergency. Results of the calculations are used to classify the incident, and the incident classification leads to decisions regarding the Laboratory's response. The main customer for plume modeling work is the Emergency Management and Response group. The technical challenge is to analyze wind conditions, perform the plume calculations, and communicate the results to emergency managers rapidly and accurately. Continual acquisition of high-quality data, maintenance of computer systems and software, and modeling skills are essential to meeting this objective.

General meteorological support

The second objective is to provide meteorological support for a broad range of Laboratory projects and programs. Site-specific meteorological data is routinely required for demonstrating regulatory compliance in the areas of air quality, water quality, waste management, as well as supporting monitoring programs in biology, hydrology, and health physics, to name a few applications. To meet this objective, continuous measurements of wind, temperature, humidity, pressure, insolation, precipitation, and surface energy fluxes are performed and archived. The program is responsible for maintaining this extensive data archive and making it easily accessible to the Laboratory and public. When requested, the program staff assists customers with meteorological data analysis and interpretation. The program also provides support to Laboratory operations coordinators with forecasts and analyses if future weather conditions (e.g., snow, heavy rain, or lightning) may adversely affect safe operations at and travel around the Laboratory. The primary challenges to meeting this objective are to maintain an archive of high-quality data, make it easily accessible to the Laboratory and community, and understand how to apply and interpret the data. Making the right measurements, managing a huge volume of data, and intelligent analysis and interpretation are instrumental in achieving this objective.

Deliverables and Customers

Definition of customer

In this document, a customer is someone who uses the services provided by the program. Because the program is entirely supported by general and administrative (G&A) funding, there is usually no charge for these services.

Types of customers

The main customer for the plume modeling capability is the Emergency Management and Response group. The services provided are detailed in a memo of understanding (ESH-17:95-270). Briefly stated, the program is responsible for maintaining a tower network to collect data for wind field calculations, maintaining the computer hardware and software needed to do the plume calculations, and maintaining the modeling skills in a state of readiness. In a phrase, the deliverable is emergency preparedness.

The customer base for the general services portion of the program is very broad. It consists of several regular customers and a much larger number of customers who may need data once or infrequently for a whole spectrum of projects. Because data requests are primarily conducted anonymously on the web, the identities of many of these customers are never known. From the few percent who do provide project descriptions, it is known that the data are used in applications that fall into the following broad categories:

- compliance
- weather information for local communities
- operations and planning
- hazard and accident analyses
- environmental studies
- support for experiments
- documentation.

Types of deliverables

The program distributes data and information to these customers from its website, known as the LANL Weather Machine, at http://weather.lanl.gov (described in Appendix B). Briefly, the following services are provided at that site:

- details and specifications of the instrument network
- current and recent conditions around Los Alamos
- current regional and national weather conditions
- weather forecast products
- local climatological information
- local meteorological data
- air quality model input data sets

Deliverables and Customers, continued

Types of deliverables, continued

The website's Local Meteorological Data section provides a series of web forms for automating data requests, enabling customers to download archived data for use in various projects. Users can also download special meteorological data sets for running some of the more common air dispersion and dose assessment models, which may be used for air permitting or demonstrating regulatory compliance. The meteorological data is pre-formatted for the intended model, requiring no additional processing on the users part (e.g., this is the way MAQ health physicists obtain meteorological data for calculating radiological dose in the CAP-88 model for EPA reporting.)

In addition to the automated distribution of information, program staff provide assistance to customers in assembling special data sets or in providing data to those who do not have direct access.

The program is also a member of the National Weather Service's Cooperative Weather Observer Network, which archives weather observations from around the country at the National Climatic Data Center (NCDC). The program has been providing this information throughout the Laboratory's history, which has resulted in a very useful database for climatological studies.

Data Objectives

Background

The program's data objectives are analyzed in this section using the EPA's data quality objective (DQO) process as a guide. The analysis is not, strictly speaking, a complete DQO analysis, but it does address the main elements of the DQO process: (1) program objectives, (2) type of information needed to accomplish objectives, and (3) estimated tolerances for errors in decisions based on the information provided.

At the outset, the importance of the site's complex terrain and its influence on meteorological variables must be recognized. Wind variables are particularly sensitive to terrain features. The 400-meter elevation difference across the site produces significant east-west gradients in the atmospheric state variables—temperature, humidity, and pressure—as well as precipitation. The precipitation gradient affects vegetation patterns, and vegetation affects surface energy and moisture fluxes. It must also be recognized that most meteorological variables display considerable temporal variability, and that variability occurs over many different time scales. Therefore, the program needs to serve a wide range of applications at the Los Alamos site that address these various spatial and temporal requirements.

Because the data objectives for the plume modeling application are quite different from those for the general support services, the data requirements for these two aspects of the program are discussed separately.

Data for plume modeling

The problem to be solved in the plume modeling application is to estimate the location and concentration of a plume of hazardous material that could endanger the health or lives of Laboratory workers and the members of the public. The program must continually maintain the capability for providing these estimates rapidly and with an accuracy that is scientifically defensible.

Important decisions are based on these plume calculations and answer these questions: (1) How should the Laboratory classify the event? (2) What are the potential exposures and what protective actions should be taken? (3) How can responders be deployed to minimize the risk of injury?

Data Objectives, continued

Data for plume modeling, continued

The information required to achieve the program's plume modeling objective is summarized in the following two tables. As indicated in the first table, the meteorological measurements must be continuous so that a plume map can be generated at any time. Sufficient historical data must also be archived so that a slowly developing event can be modeled or a release can be analyzed after the event. In addition, because the Laboratory's emergency planning zone (EPZ) covers approximately 300-square kilometers of complex terrain, a multiple-tower network is essential to account for the spatial variability in the wind field.

The wind field at the time of the release is used to determine the initial direction and speed of the plume from the point of release. Subsequent changes in the plume trajectory must be accounted for by continuously updating the wind field (currently every 15 minutes). The growth in the size of the plume as it travels downwind is calculated with a dispersion parameter, and this parameter is a function of distance from the source and atmospheric stability.

The meteorological information needed for plume modeling is listed in the table below. The variables marked with an asterisk are considered essential; the remaining variables are very useful.

Meteorological Variable	Application	Quality Objective	Sampling
Wind speed*	Wind field calculation	±0.5 m/s	Continuous at multiple stations
Wind direction*	Wind field calculation	±5 deg	Continuous at multiple stations
Wind direction variance*	Stability determination	10%	Continuous at multiple stations
Vertical velocity variance	Stability determination	10%	Continuous at multiple stations
Mixing depth	Stability determination	±50 m	Every hour when atmosphere is stable and during the early growth period
Precipitation	Washout algorithm	5%	Continuous at multiple stations
Temperature	Evaporation	±0.3°C	Continuous at one station
Global radiation	Evaporation algorithm	10%	Continuous at west and east edges of site
Soil temperature	Evaporation algorithm	±0.3°C	Every hour at one station
Wind profile	Interpretation of plume calculation and trajectory forecasting	±20 deg and ±1 m/s	Every hour up to 700 m above ground level (AGL)
Weather forecast	Trajectory forecasting	Not applicable	Continuous access to standard weather products

Data Objectives, continued

Data for plume modeling, continued

The scenario information needed for plume modeling is listed in the table below. Scenario-related information is provided to the program from other sources and entered into the Meteorological Information and Dispersion Assessment System (MIDAS) files (see the Appendix). All the information listed in this table is considered essential.

Information	**Application**	**Quality Objective**
Quality or rate and duration	Source term	Order of magnitude
Material released	Dose or toxicity	Not applicable
Sensible heat release	Plume rise	Order of magnitude
Type of release (chemical)	Calculate release rate	Not applicable
Building dimensions	Wake effects	±20%
Stack parameters	Plume rise	±20%
Building location	Source location	±100 m
Time of release	Transport and dispersion calculation	±15 min
Material properties	Calculate evaporation, dose, toxicity, transport within the plume	From standard tables
Map information	Plume mapping	±100 m

Data for plume modeling, continued

Uncertainties. Because plume modeling is an imprecise science, emergency manager should be prepared to tolerate an order of magnitude uncertainty in estimates of concentration or dose. Incomplete knowledge of the event scenario and the resulting source term are the major contributors to this uncertainty, and the remainder can be attributed to errors in locating the plume, and, to a lesser degree, to errors in modeling the dispersion. Given the uncertainty in determining concentration (or dose), the design objective is to locate the plume to ±1 kilometer.

Data Objectives, continued

Data for plume modeling, *continued*

Defining plume trajectory is a complicated (and largely indeterminate) function of tower density, meteorological conditions, wind field modeling assumptions, and accuracy of the wind measurements. A study of the adequacy of the program's plume trajectory capabilities by Lee et al. (1994) suggests that out to a range of 4 kilometers from a source, the random error in locating a plume is less than or equal to 1 kilometer 90 percent of the time. The program achieves this accuracy using wind direction measurements accurate to ±5 degrees, a four-tower network, and a $1/r^2$ wind field model.

Data for general applications

Variety of applications. In addition to the plume modeling application, meteorological data are used in a wide variety of problems at the Laboratory. As mentioned previously, the details of many of these applications are not known because customers have not provided this information when downloading data. See the list of categories of applications provided earlier in the block "Types of customers" on page 7.

Variables. The following table shows some of the typical applications requiring use of the program's meteorological data. To serve this broad range of applications, it is necessary to measure a comprehensive set of variables at multiple locations. Furthermore, many applications require measurements over an extended period of time. For example, establishing climatic normals requires a 30-year dataset; extreme value analysis may require a shorter or longer dataset.

Because of the significant change in elevation across the site, it is necessary to operate stations at the upper and lower elevations of the site. At these locations, additional variables are measured to characterize the climate.

Data Objectives, continued

Data for general applications, *continued*

Data accuracy. The use of meteorological data measured at the Laboratory varies significantly, from dispersion modeling to climatological analyses to operational forecasting. This broad range of applications makes it impractical to establish formal limits on acceptable measurement error and uncertainty. As a result, the data are obtained by using industry-standard meteorological instrumentation, with data accuracy meeting standards acceptable to professional meteorologists.

Additional measurements are made to compute derivative variables that support the program's internal needs for quality control and provide a more complete understanding of local meteorological conditions. For example,

- reflected short-wave radiation is used to calculate albedo, which is used to calibrate snow cover estimates or is used in dispersion modeling applications;
- ground heat flux and long-wave radiation are used in surface energy balance calculations, which are used to check estimates of moisture flux; and
- soil moisture is measured to obtain the ground heat flux.

Data Objectives, continued

Data for general applications, *continued*

A sample of problems and decisions requiring meteorological input are listed in the table below.

Problem Area	Problem	Decision	Meteorological Input
Compliance	National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP) reporting (dose calculations)	Are we in compliance? (dose to the maximum exposed individual [MEI] < 10 mrem?)	Wind statistics
	National Pollutant Discharge Elimination System (NPDES) reporting (sewage sludge drying)	Are we in compliance? (temperature > 32°F for 90 days?)	Temperature
	NPDES reporting (storm-water runoff sampling)	Should the runoff be sampled? (precipitation > 0.1 in.?)	Precipitation
	Resource Conservation and Recovery Act (RCRA) reporting (leakage to environment)	Can the loss of waste be explained by evaporation?	Evapotranspiration
Operations and planning	Design (heating, ventilation, and air conditioning [HVAC] systems)	What capacity is needed?	Temperature
	Utility planning	How much natural gas should be purchased next month?	Climatological summaries and recent temperature history
	Design (structural)	What is the potential snow and wind loading for this area?	Precipitation and snow and wind gusts
	Testing (high-voltage problem at Los Alamos Neutron Scattering Center [LANSCE])	Are there environmental factors?	Temperature, dew point, precipitation
Hazard analysis	Safety analysis report (SAR) preparation	What is the 95% worst dose at site boundary? What is the lightning flash density for Los Alamos?	Wind and stability Lightning
	Hazards Assessment (DOE Order 151.1A)	What is the Laboratory's emergency planning zone?	Wind and stability
	Dose reconstruction	What was the dose to the public?	Wind and stability

Data Objectives, continued

A sample of problems and decisions requiring meteorological input (continued)

Problem Area	**Problem**	**Decision**	**Meteorological Input**
Environmental studies	Contamination	Can barometric pumping explain diffusion of underground plumes of volatile organic contaminants?	Pressure fluctuations
	Hydrology	What is the recharge rate to aquifers?	Moisture flux
	Biology	What factors control fluctuations in reptile populations?	Precipitation
	Contamination	Can heavy flooding explain the movement of contaminated soils?	History of precipitation
Support for experiments	CO_2 laser performance	What was the character of the surface layer during laser operation?	Wind, turbulence, humidity
	Neutron transmission through samples of octane	What was the density of the sample?	Temperature
Documentation	Arbitration	Can delays in construction be explained by adverse weather conditions?	Temperature, snowfall, precipitation
	Occurrence investigation	What were conditions at the time of the accident?	Wind, state variables, precipitation
	Wildfire dispersion of contaminants	How were contaminants possibly dispersed by the fire?	Wind, temperature, precipitation, stability
Safety	Lightning detection	Is it safe to continue outdoor activities?	Lightning
	Flash flooding	Should access to canyons be restricted?	Precipitation
	Snowfall	Should the Laboratory close due to unsafe road conditions?	Snowfall, precipitation, temperature

Organization and Responsibilities

MAQ responsibilities

The Meteorology and Air Quality (MAQ) Group of the Risk Reduction and Environmental Stewardship (RRES) Division is responsible for the meteorological monitoring program at the Laboratory. Day-to-day management of the program is the responsibility of the project leader, who reports directly to the MAQ group leader. See the MAQ Quality Management Plan (MAQ-QMP) for a full description of the group organization and chain of authority.

Division of work

For convenience, program work is divided into five components: measurements, data management, data analysis and forecasting, modeling, and data accessibility. Work in these five components is divided into "base program work" and "quality improvement work." Base program work is continuous, routine work essential to providing customers with basic services. Quality improvement work consists of short-term projects designed to fix or improve some aspect of the program. Work assignments include base program responsibilities that change little from year to year plus one to several quality improvement projects. Details of staff work assignments are reviewed annually and kept on file in the group office.

Base program responsibilities

A summary of the base program responsibilities assigned to various staff members is given in the table below.

Job Title	Base Program Responsibilities
Project Leader	Plan, coordinate, and participate in program work; oversee program quality assurance; ensure program goals are achieved in a cost-effective manner; submit budget and staff performance data to group leader.
Meteorologist	Maintain MIDAS skills; handle requests for data and information; maintain scenario information; conduct analyses and write reports; make data quality decisions; design and test new program features.
Senior Programmer	Build, maintain, and document the major software components of the program; contribute appropriate computer science solutions and tools to achieving program objectives; oversee computer systems administration.
Computer Systems Administrator	Maintain UNIX systems in a reliable, secure state; maintain software and hardware support contracts; perform backups; assist users; perform routine data processing and assist in analyses.

Organization and Responsibilities, continued

Job Title	Base Program Responsibilities
Instrument Technician	Maintain the measurement network, including procurement, acceptance testing, installation, calibrations, inspections, data logger programming, and documentation; assist with data quality control activities.

Section 2

Personnel Training and Qualification

Training and Professional Development

MAQ education

Program personnel annually review Laboratory and group training requirements, and they review all program-specific procedures applicable to their job assignments. Special training is required for those involved in electrical work. Training for MAQ personnel is performed and documented according to MAQ-024.

Program staff are encouraged to continue their education in their individual areas of expertise; formal training in computer science, meteorology, and instrumentation is especially relevant to program work. In addition to on-site training offered through the Laboratory, attendance at professional meetings is encouraged—to the extent the budget allows. Professional growth is also fostered through collaborations with personnel in the Scientific Software Engineering Group (CCN-12) and the Atmospheric, Climate, and Environmental Dynamics group (EES-2).

Personnel Qualifications

Summary of qualifications

Details of the qualifications of the program personnel are on file in the MAQ Group Office. The table below summarizes these qualifications and indicates the mix of skills and level of proficiency required by program work.

Job Title	Qualifications
Instrument Technician	High-level electromechanical technician with formal training in electronics and several years of experience. Good understanding of meteorological sensors, data loggers, and general principles of engineering and measurement science.
Computer Systems Administrator	Intermediate-level UNIX system administrator. Familiar with basic system administration tools and processes plus a good working knowledge of UNIX commands and utilities. Proficient at data processing, including some programming skills.
Senior Programmer	Staff member with an MS degree in physics and several years of programming experience. Proficient in C and perl programming languages. Has a working knowledge of client-server technology and computer hardware.
Meteorologists	Staff members with MS and PhD degrees in meteorology. Backgrounds include training in turbulence and diffusion, boundary layer theory, and weather forecasting. Experience includes several years of data analysis and interpretation.

Section 3

Quality Improvement

Overview

Policies

Policies governing quality improvement and corrective action are given in Section 3 of the MAQ QMP.

Task list

In addition, the project leader keeps a running list of items that require repair or improvement (see "Planning" in the first table in Section 4). Items on this list are developed into formal work assignments that appear in personnel job descriptions, which are reviewed at least annually. This list of tasks is designed to address program deficiencies and opportunities for improvement in efficiency and quality. All members of the program contribute to this list through observations in their own specialty areas and discussions with the project leader. Customer feedback obtained from Weather Machine log files and email is also an important source of ideas on how to improve the program. Progress on quality improvement is reported every quarter to the group leader.

Section 4

Documents and Records

Documents

Program documents

The program strives to develop and maintain formal documentation that establishes policy, prescribes work, specifies requirements, and establishes design. This documentation is listed in the table below and is all stored at TA-59-0001, room 178, in the indicated notebooks.

Topic	Description or Title	Notebook
Procedures	Procedures that document important routine work—controlled documents	“Procedures used in the Meteorological Monitoring Program”
Program Responsibilities in Emergency Response	Memo: “ESH-17 Meteorology Support for FSS-20”	“Meteorology Program Documents”
MAQ Quality Assurance	“Quality Management Plan for the Meteorology and Air Quality Group (MAQ)”—controlled document	“Meteorology Program Documents”
Program Quality Assurance	“Quality Assurance Project Plan for Meteorological Monitoring”—controlled document	“Meteorology Program Documents”
Program Description	“Meteorological Monitoring Plan”	“Meteorology Program Documents”
Planning	“Planned Improvement for the MAQ Meteorology Program”	“Meteorology Program Documents”
DOE Orders and Standards	Various	On shelf in room 178

Records

Program records

The program strives to generate a complete record of methods used, work completed, results of its measurement and analysis activities, and data quality. Records associated with the various program components are listed in the following tables; all records are stored at TA-59-0001.

General records

Record	Description	Location
Progress reports	Quarterly progress reports to group management	Notebook, "Meteorology Program Progress Reports," room 178

Records associated with measurements

Record	Description	Location
Meteorological station workbooks	Station engineering drawing, wiring diagrams, instrumental configuration, and data logger programs	Notebook by station, room 176
Calibration activity workbooks	Notes on all instrument calibration and repair activity	Various notebooks, room 176
Purchase requests	—	File cabinet, room 176
Vendor literature	—	File cabinet, room 176
Audit reports	Results of the annual independent performance audits	Various notebooks, room 178
Meteorological site logbook	Record of all events at the stations, including instrumentation failure, changes in data acquisition, downtime for audits and repairs, and a record of data editing	Room 178
Station descriptions	Types of measurements made, physical description of the area around the station, location and elevation, and data quality notes	Weather Machine/Local Meteorological Data

Records, continued

Records associated with data management

Record	**Description**	**Location**
Code documentation	User guides to the important, locally developed C and PV-Wave executables used in data processing and analysis	Notebook, "User's Guide to UNIX Software for Meteorological Operations," room 178
Data quality notes	Notes on general limitations on data quality as a result of changes in instrumentation, siting, sampling, etc.	Weather Machine/Local Meteorological Data
Data files	Binary data files Text data files	Sibyl/data Integrated Computing Network (ICN) Common File System (CFS)
Data edits	Hard copy Electronic	Room 178 Sibyl/data/edits
Electronic logs	System status reports, error logs, feedback from customers	Various directories/files on Sibyl
Backup tapes	Backups for UNIX machines	Stored at room 181 daily and weekly; stored in the group office quarterly
Real-time plots and tables	Various graphical and tabular summaries of local conditions	Weather Machine/Current and Recent Conditions around LANL
Weather observations	Handwritten records of daily temperature extremes, precipitation, and weather events, dating back to 1910	Hard copy in room 178, electronic at Sibyl/data/met_archive
Routine data reports	Monthly summary Precipitation tables Annual summary Wind roses Normals and extremes	Weather Machine/Current and Recent Conditions around LANL and Local Climatological Information

Records, continued

Records associated with analysis

Record	Description	Location
Technical reports	Official LANL reports describing results of analyses of local meteorological measurements. See bibliography in "Meteorological Analysis Notebook."	Shelved in room 178
Work in progress	Draft text and plots on various topics	"Meteorological Analysis Notebook," room 178

Records associated with modeling

Record	Description	Location
MIDAS manuals	Vendor-supplied manuals that document plume calculation methods, system parameters, and system editors	Shelved in room 178
MIDAS user's guide	User manual for running MIDAS	Shelved in room 178
MIDAS alterations	Documentation of changes to scenarios (radiological and chemical) within MIDAS	"MIDAS Changes Notebook," room 178

Section 5

Work Processes

Overview

Components

Program work naturally divides into the work processes or components listed in the table below. Details of these processes are given in Appendix B. Material in Appendix B is taken from Section C of the most current version of the Meteorological Monitoring Plan, but it is subjected to an annual review and revision to meet the requirements of this QAPP.

Process	**Description**
Measurements	Made across a comprehensive network of instrumented towers and additional precipitation stations. (MAQ-401, "Meteorological Tower Climbing and Support"; MAQ-402, "Calibration and Maintenance of Instruments for the Meteorology Monitoring Program"; MAQ-404, "Repairing, Maintaining, and Calibrating Meteorological Instruments in the Field")
Data management	Includes all that is necessary to acquire, process, store, retrieve, and analyze large amounts of data and other meteorological information. Computer system management and software development are part of this effort. (MAQ-403, "Routine Meteorological Data Processing"; MAQ-405, "Processing Meteorological Data on the CCVAX")
Analysis and interpretation	Provides the necessary understanding of meteorological conditions and model limitations needed for intelligent application of the program's services.
Plume modeling	Consists of maintaining the information, software, hardware, and the modeling skills needed to do plume calculations (MAQ-407, "Altering MIDAS Scenarios").

Section 6

Design

Program Design Activity

Basic elements

The basic elements of the program—standard meteorological measurements, plume calculations, and data storage—were initially designed to meet the basic monitoring requirements set forth in the DOE orders. Over the years these elements have been continually redesigned to reflect advances in technology, to reflect changes in ideas of what is acceptable and defensible, and to meet the increasing demand for meteorological information. The internet has been utilized to make this meteorological information readily available to the Laboratory community, with the development of the program's website 'The Weather Machine' (http://weather.lanl.gov).

Current design and instrument selection

Current design work is based the program's mission, data objectives, and the requirements that govern meteorological monitoring, as presented in Section 1. As discussed in the Appendix, recognized standards and appropriate scientific methods are employed.

Although many design decisions are left to the discretion of program personnel, decisions on major changes, such as a change in computer architecture, software for dispersion modeling, or tower network design, are based on extensive investigations that may include market surveys and input from experts outside of the program.

Design considerations

General design considerations are listed in the table below.

Element	Design Requirement
Instrumentation	Must be capable of continuous operation in all weather conditions
Computer systems	Must handle computation- and graphics-intensive applications in a secure and reliable manner
Station network	Must measure adequately the variance in all important meteorological variables across a large site having complex terrain
Archive	Must be accessible and contain useful and accurate data
Automation	Improve cost effectiveness

Continued on next page.

Program Design Activity, continued

Element	**Design Requirement**
Plume modeling systems	Must be appropriate for complex terrain where chemicals and radiological materials are used at multiple facilities

Section 7

Procurement

Procurement

Procured items and services

The program procures critical items and services in accordance with the MAQ QMP and LANL Business Operations Division (BUS) policies and procedures for procurement. Specifications are established to meet design requirements, and then commercially available equipment is evaluated against these specifications.

Section 8

Inspection and Acceptance Testing

Inspections and Acceptance Testing

Instrument inspection and calibration

All instruments are inspected and calibrated before installation. When new types of sensors are to be added, they are set up on a trial basis for several weeks or months for evaluation before the data are added to established station data files and made accessible to the Laboratory community. See procedures MAQ-402 ("Calibration and Maintenance of Instruments for the Meteorology Monitoring Program") and MAQ-404 ("Repairing, Maintaining, and Calibrating Meteorological Instruments in the Field") for the calibration intervals and procedures.

Section 9

Management Assessments

Internal Assessments

Project and program assessments

The Meteorology and Air Quality Group conducts internal management assessments of all projects and programs in the group in accordance with MAQ-029, "Management Assessments." This procedure requires periodic assessment by the group leader of the effectiveness of projects and programs. These assessments are documented and filed as records.

Responding to assessments

When violations of requirements are found during a management assessment, a deficiency report is initiated to document the violation. Corrective actions are tracked and documented in accordance with MAQ-026, "Deficiency Reporting and Correcting."

To assist group management in tracking developments and progress in meteorology, quarterly reports are sent to the group leader. These reports highlight improvements in the quality of the program and track Laboratory use of program services.

Section 10

Independent Assessment

External Audits

Contractor audits

The MAQ QMP stipulates that independent assessments (audits) will be conducted throughout the group, as specified by the group leader, to verify compliance with all program requirements and all aspects of the group QMP (see Section 10, MAQ-QMP).

Periodic performance audits of the measurement component of the program are conducted by a qualified contractor. Formal reports are shelved at TA-59-0001, room 178.

Click here to record “self-study” training to this procedure.

APPENDIX A

References

Baars et al. 1998: J. A. Baars, H. D. Holt, and G. Stone, "Meteorological Monitoring at Los Alamos," Los Alamos National Laboratory document, LA-UR-98-2148 (May 1998).

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APPENDIX B

Program Implementation

The following appendix is Section C of "Meteorological Monitoring at Los Alamos".

C. Program Implementation

1. Measurements

a. Instrumentation

High quality meteorological measurements are the foundation of the program. The objective is to deliver a continuous stream of data with a recovery of at least 95% (for in situ measurements). Program measurements meet or exceed recommendations found in EPA 1987, EPA 1989, NWS 1989, and EPA 1981.

Over 100 instruments, consisting of over 20 different types of sensors, are used in the network. All instruments are of high quality and are purchased from reputable manufacturers. Automatic range checking is employed for a real-time verification of the incoming data. On a weekly basis, a meteorologist will perform further verification of all data, looking for possible instrument problems. In this way, the instrumentation undergoes continuous verification. The entire network also undergoes periodic calibration inspections and refurbishment as required by the instrumentation. All test equipment and calibration standards are traceable to the National Institute of Standards and Technology (NIST). An external audit is performed periodically and results from these audits are available at the Meteorological Laboratory at TA-59, Building 1. The types of instruments used in the network are given in Table 13-2. See Table 13-3 for definitions of variables and symbols.

In general, instruments in the network operate continuously under local weather conditions. Occasionally snowstorms cause icing on wind instruments and upward-facing radiometers, and lightning strikes to towers can cause damage to instruments. Considerable attention has been given to lightning protection however, and although the Los Alamos area has one of the highest flash densities of lightning in the United States, data loss caused by lightning strikes is rare.

All wind instruments are supported by towers of open-lattice construction with instruments mounted on booms. To reduce flow distortion from the tower, booms face westward into the prevailing wind direction and their lengths are more than twice the tower width. The booms are attached to an elevator that can be lowered for instrumentation inspection. Booms are not used for the Pajarito Mountain tower, which has its instrumentation situated on the top of an open-lattice, 36-meter, cellular phone tower. For the MDCN tower, the wind instruments are mounted at the top of the 10-meter tower. Towers, guy lines, and elevators are inspected periodically by a licensed tower erection contractor for wear and safe operation. Results of the last inspection are discussed in an inspection report by Tower Systems, Inc., 1997.

Table 13-2. Instruments Used Throughout the Network

Variable	Instrument Type	Number Used
Wind variables		
u	Propeller-driven AC tachometer	17
u	Sonic anemometer	2
θ	Vane-driven potentiometer	17
w	Propeller-driven DC tachometer	16
w	Sonic anemometer	2
Atmospheric state variables		
T	Thermistor (aspirated)	23
p	Variable ceramic capacitor	3
h	Hygroscopic capacitor	6
q	Infrared optical hygrometer	2
Precipitation variables		
r	Heated tipping bucket with wind screen	8
s_d	Ultrasonic measurement of distance to snow surface	2
l	Optical and rf sensors	1
Radiative fluxes		
$K\downarrow$	Pyranometer (aspirated)*	6
$K\uparrow$	Pyranometer	2
$L\downarrow$	Pyrgeometer (aspirated)	2
$L\uparrow$	Pyrgeometer	2
Subsurface measurements		
T_s	Thermistor	10
Q_g	Thermopile	4
χ_w	Time domain reflectometer	4
Fuel moisture and temperature		
W_{10}	Capacitance of wood dowel	1
T_{fuel}	Thermistor (within wood dowel)	1

* NOTE: The MDCN pyranometer is not aspirated.

b. Observed Variables

Meteorological variables measured by the program can be grouped into the categories of wind, atmospheric state, precipitation-related, radiative fluxes, eddy heat fluxes, subsurface measurements, and fuel moisture. Below is a brief description of each category, including its importance to the program.

- *Wind variables*. The tower network provides continuous measurements of mean wind speed, wind direction, and turbulence at multiple levels over the Pajarito Plateau, on top of Pajarito Mountain, and in Los Alamos and Mortandad Canyons. These data are critical to emergency preparedness, dispersion modeling for regulatory compliance, and planning studies.

- *Atmospheric state variables*. Continuous measurements of temperature, pressure, and moisture variables are used to document the state of the atmosphere. Temperature applies to a wide range of planning studies and documentation, and it is one of the inputs to the evaporation algorithm for chemical plume modeling. Pressure is used to calibrate several other environmental measurements and to calculate the potential temperature lapse rate. Atmospheric moisture variables are used in engineering design, estimates of evapotranspiration, and forecasting.

- *Precipitation-related variables*. One of the most frequently requested data types is precipitation data. It is used by biologists, hydrologists, and those involved with regulatory compliance, and it is an input to the washout algorithm for modeling radioactive plumes. Snowfall and snow depth measurements are reported to the NWS and the NCDC and are used for various forms of documentation.

  The lightning data represent the number of strokes detected in a given period over a range that depends on sky conditions and the natural variation in lightning flashes (estimated to be 5 kilometers to 50 kilometers). Lightning stroke rate is a sensitive indicator of the electrical power generated by a thunderstorm, and this power is closely related to the severity of the weather (wind, hail, and rain) associated with the storm. Because the lightning detector is capable of detecting intracloud lightning, which usually precedes the more dangerous cloud-to-ground lightning by 10 to 30 minutes, it has some early warning potential. Also, the occurrence of dry thunderstorms can be detected by identifying times when lightning is detected but no precipitation is measured. Dry thunderstorms have the potential for igniting wildfires which is a concern of fire managers.

- *Radiative fluxes*. Short-wave and long-wave irradiances are used to estimate the net radiative forcing at the surface, which is important in the surface energy balance. The downward short-wave irradiance is used to estimate atmospheric stability, calculate evaporation, and document sky conditions for experiments. The upward short-wave irradiance provides information on the condition of the surface, or the albedo, such as determination of snow cover or ground wetness, which is also used in experiments. The downward long-wave irradiance provides cloud cover information at night.

- *Eddy heat fluxes*. Eddy heat fluxes describe how the net radiative forcing at the surface is dissipated. Latent heat flux is related to evapotranspiration, which is being used by a number of environmental scientists, including hydrologists interested in calculating the water budget for the area.

- *Subsurface measurements*. Measurements of soil temperature, soil moisture, and ground heat flux represent an attempt to document the response of the upper layers of the soil to atmospheric forcing. The ground heat flux completes the surface energy balance, which in turn allows for quality control of the eddy flux measurements. The subsurface measurements were modified in 1998 to improve the measurement of the ground heat flux. These modifications included adding the measurement of soil moisture, spatial averaging of soil temperature, and the addition of two measurement levels.

- *Fuel moisture and temperature*. Fine-dead fuel moisture and temperature is directly related to the ignition potential, and therefore is an important parameter for fire specialists in assessing various aspects of local fire danger. The 10-hour fuel moisture is measured, and a modified National Fire Danger Rating System (NFDRS) algorithm is then used to estimate the one-hour fuel moisture. The one-hour fuel moisture is especially important because it can change rapidly, and fires usually begin with the ignition of fuels in this category. The 10-hour fuel moisture is also important in determining the potential for ignition as well as fire sustainability.

Table 13-3, parts (a) through (h), define all the meteorological variables measured or computed across the network. The tables are organized into sections corresponding to variable type: wind, atmospheric state, precipitation-related, radiative energy fluxes, eddy heat fluxes, subsurface measurements, and fuel moisture and temperature.

Symbols given in the first column of Table 13-3 (a)–(h) are conventionally used in meteorological literature and are standard in program documentation. Symbols on the left side of the first column denote the primary variables, which are those obtained from an appropriately conditioned signal from an instrument's transducer. Indented symbols in the first column represent variables that are calculated, usually from the primary signal. In a few cases (e.g., dew-point temperature) these variables are calculated from multiple signals.

The second column shows the variable names used in locally developed data processing software. For temperature and wind variable names, an *n* suffix, if present, denotes that measurements are made at multiple levels on the tower.

The third column gives the units of measurement for the given variables. These are generally standard SI units although exceptions are found (e.g., millibars are used instead of Pascals for pressure).

The variables are defined in the fourth column. Unless otherwise noted, variables are based on a 15-minute sampling period. The integral means that the integrand has been integrated from 0000–2400 Mountain Standard Time (MST). Resolution of the archived data and estimated accuracy are given in parentheses. For example, (0.1, ±0.3˚C) means that the data are archived to the nearest 0.1˚C and the accuracy is estimated at ±0.3˚C. When the accuracy is undetermined, two asterisks (**) are inserted. Accuracy estimates are based on instrument accuracy as stated by the manufacturer, adjusted to reflect uncertainties in instrument alignment, exposure, and filtering and sampling effects, when appropriate.

Table 13-3. Symbols, Variable Names, Units, and Definitions

Part (a) Time Variables

Symbol	Variable Name	Variable Definition
	year	Year
t	doy	Day of year (1 to 365 or 366 for a leap year)
	time	Mountain Standard Time (1min, ±1 min)

Part (b) Wind Variables

Symbol	Variable Name	Units	Variable Definition
U	spdn	ms^{-1}	Horizontal scalar wind speed (0.1, ±0.1)
σ_u	sdspdn	ms^{-1}	Standard deviation of wind speed
$\overline{U}$	avgspdn	ms^{-1}	24-hour average wind speed
U_{mx}	mxgstn	ms^{-1}	Maximum instantaneous wind gust
t_{mx}	tgstn	hhmm	Time of occurrence of maximum gust
U_{mx1}	mx1gst	ms^{-1}	Maximum 1-minute wind gust in 24 hours based on non-overlapping 1-minute averages
t_{mx1}	t1gst	hhmm	Time of the maximum 1-minute gust
u'		ms^{-1}	Horizontal scalar wind speed fluctuation (not logged—see friction velocity squared, u_*^2)
θ	dirn	degrees	Unit vector mean wind direction (1, ±5, measured clockwise from true north)
σ_θ	sddirn	degrees	Standard deviation of wind direction
θ_{mx}	dirgstn	degrees	Direction of the maximum instantaneous gust
θ_{mx1}	dir1gst	degrees	Direction of the maximum 1-minute gust
w	wn	ms^{-1}	Vertical velocity (0.1, ±0.1, positive upward)
w'		ms^{-1}	Vertical velocity fluctuation (not logged—see friction velocity square, u_*^2, and fluxes of heat, Q_h and Q_e
σ_w	sdwn	ms^{-1}	Standard deviation of the vertical velocity
u_*^2	fvel2	m^2s^{-2}	Friction velocity squared (0.1, **) $u_*^2 = -\overline{u'w'}$ = momentum flux per unit density (positive downward)

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (c) Atmospheric State Variables			
Symbol	**Variable Name**	**Units**	**Variable Definition**
T	tempn	˚C	Air temperature (0.1, ±0.3)
T_{mx}	mxtemp	˚C	Maximum instantaneous temperature
t_{mx}	tmxtemp	hhmm	Time of maximum temperature
T_{mn}	mntemp	˚C	Minimum instantaneous temperature
t_{mn}	tmntemp	hhmm	Time of minimum temperature
T_{mid}	midtemp	˚C	Midnight temperature (*laarc* and *wrarc* only)
T'		˚C	Temperature fluctuation (not logged—see sensible heat flux, Q_h)
p	press	mb	Atmospheric pressure (0.1, ±0.6)
p_{mx}	mxpress	mb	Maximum instantaneous pressure
p_{mn}	mnpress	mb	Minimum instantaneous pressure
h	rh	%	Average relative humidity (1, ±10)
$\bar{h}$	avgrh	%	24-hour average relative humidity
h_{mx}	mxrh	%	Maximum relative humidity
h_{mn}	mnrh	%	Minimum relative humidity
h_{mid}	midrh	%	Midnight relative humidity (*laarc* and *wrarc* only)
T_d	dewp	˚C	Dew point temperature (0.1, **) $T_d = f(VP(h,SVP(T,h)))$, where VP and SVP are vapor pressure and saturation vapor pressure; when $T < 0$˚C, T_d is the frost point
$\bar{T}_d$	avgdewp	˚C	24-hour average dew point temperature
T_{dmx}	mxdewp	˚C	Maximum instantaneous dew point
T_{dmn}	mndewp	˚C	Minimum instantaneous dew point
q	ah	g m^{-3}	Absolute humidity (0.01, above 0˚C: 1.0˚C, below 0˚C: 1.5˚C [accuracies given by manufacturer after converting to T_d])
$\bar{q}$	avgah	g m^{-3}	24-hour average absolute humidity
q'		g m^{-3}	Absolute humidity fluctuation (not logged)
ρ		kg m^{-3}	Atmospheric density (kg m^{-3}, not logged) $\rho = p/RT$, where R is the gas constant for dry air (= 287 J kg^{-1} K^{-1}), p is pressure (mb), and T is temperature (K)

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (d) Precipitation-Related Variables			
Symbol	**Variable Name**	**Units**	**Variable Definition**
r	precip	in	15-minute total precipitation, includes rain and melted frozen precipitation (0.01, ±0.05r)
$\hat{r}$	tprecip	in	24-hour total precipitation
s_d	snowd	in	Snow depth (0.1, ±0.4)
s_{dmid}	midsnowd	in	Midnight snow depth (0.1, ±0.4)
s_f	snowf	in	Snowfall (0.1, ±0.4). Estimated from increases in snow depth when liquid precipitation, *r*, is being recorded.
l	lstks	unitless	Number of lightning strokes in 15 minutes within a range that varies from a few km to approximately 50 km. A lightning “flash” may consist of 1 to 30 strokes, with four strokes being the average.
$\hat{l}$	totlstks	unitless	Number of lightning strokes in 24 hours

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (e) Radiative Energy Fluxes (Irradiances are measured with radiometers oriented horizontally.)			
Symbol	**Variable Name**	**Units**	**Variable Definition**
$K\downarrow$	swdn	W m^{-2}	Shortwave irradiance, or global radiation, includes diffuse and direct beam in the 0.285-µ to 2.800-µ waveband (1, ±0.035 $K\downarrow$ [zenith angle 0–70˚], ±0.065 $K\downarrow$ [zenith angle 70–90˚], positive downward)
$\hat{K}\downarrow$	swedn	MJ m^{-2}	24-hour total shortwave radiative energy $K\downarrow = \int_0^{24} K\downarrow dt$ (0.01, **)
$K\uparrow$	swup	W m^{-2}	Reflected shortwave irradiance, positive upward
$\hat{K}\uparrow$	sweup	MJ m^{-2}	24-hour total reflected shortwave radiative energy $K\uparrow = \int_0^{24} K\uparrow dt$
$L\downarrow$	lwdn	W m^{-2}	Long-wave atmospheric irradiance in the 3.5-µ to 50-µ waveband (1, ±0.06*$L\downarrow$, positive downward)
$\hat{L}\downarrow$	lwedn	MJ m^{-2}	Downward long-wave energy received in 24 hours $L\downarrow = \int_0^{24} L\downarrow dt$ (0.1, **),
$L\uparrow$	lwup	W m^{-2}	Terrestrial irradiance, positive upward
$\hat{L}\uparrow$	lweup	MJ m^{-2}	Upward long-wave energy received in 24 hours $L\uparrow = \int_0^{24} L\uparrow dt$
Q^*	netrad	W m^{-2}	Net irradiance (1, **, positive downward) $Q^* = K\downarrow + K\uparrow + L\downarrow + L\uparrow$
$\hat{Q}^*$	nete	W m^{-2}	24-hour net radiative energy received $Q^* = \int_0^{24} Q^* dt$ (0.1, **)

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (f) Eddy Fluxes of Heat			
Symbol	**Variable Name**	**Units**	**Variable Definition**
Q_h	sheat	W m^{-2}	Sensible heat flux, produced by turbulence in the presence of a temperature gradient (1, **, positive upward) $Q_h = 1.08 C_p \overline{w'T'_v} + 0.1 Q_e$, where C_p is the specific heat of dry air at constant pressure (= 1006 J kg^{-1} K^{-1} at 10˚C)
$\hat{Q}_h$	sheate	MJ m^{-2}	24-hour total sensible heat energy (0.01, **) $\hat{Q}_h = \int_0^{24} Q_h dt$
Q_e	lheat	W m^{-2}	Latent heat flux, produced by turbulence in the presence of a gradient in the absolute humidity (1, **, positive upward) $Q_e = L\overline{w'q'}$ where L is the latent heat of vaporization of water (≈ 2480 J g^{-1} at approximate annual mean temperature of 46˚F)
$\hat{Q}_e$	lheate	MJ m^{-2}	24-hour total latent heat energy (0.1, **) $\hat{Q}_e = \int_0^{24} Q_e dt$ Note: the evapotranspiration, e, in mm of water over the 24-hour period is given by $e = 0.403\hat{Q}_e$

Part (g) Subsurface Measurements			
Symbol	**Variable Name**	**Units**	**Variable Definition**
Q_f	sflux	W m^{-2}	Subsurface soil heat flux (not logged—see soil heat flux, $\hat{Q}_g$)
T_s	stempn	˚C	Soil temperature (0.1, ±0.3)
χ_w	smoistn	%	Volumetric soil moisture content. For a given volume of soil, the volumetric soil moisture content is the percentage of that volume of soil that is water.
$\hat{\chi}_w$	avgsmoist	%	24-hour average soil moisture.
Q_g	gheat	W m^{-2}	Ground heat flux at the surface produced by a temperature gradient at the surface (1, ±0.05) (positive downward)
$\hat{Q}_g$	gheate	MJ m^{-2}	Soil heat flux at the surface $Q_g = Q_f + C\Delta z\left(\frac{\Delta T_s}{\Delta t}\right)$, where C is heat capacity, Δz = 0.08 m, and Δt is 300 s.

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (h) Fuel Moisture			
Symbol	**Variable Name**	**Units**	**Variable Definition**
W_{10}	fm10	%	10-hour fine dead fuel moisture (1, when FM10 = 0–12%: 1.9%, when FM10 =12–30%: 3.6%, when FM10 > 30%: 16%). W_{10} is equal to the percent water (by weight) in a dead fuel of diameter < 1/4”.
W_1	fm1	%	1-hour fine dead fuel moisture, estimated from *fm10*. $W_1 = f(W_{10}, K\downarrow, T, h)$

Table 13-4 contains measurement level (*n*), measurement height above ground (*z*), and the set of variables measured every 15 minutes at each of the seven towers. Towers TA-6 and TA-54 are similarly equipped, with the exception that TA-6 includes an additional measurement level (4) and also provides snow measurements. Likewise, towers TA-41, TA-49, and TA-53 are similarly equipped, except for the missing measurement level (3) and no precipitation measurements at TA-41.

Table 13-5 repeats Table 13-4 except for 24-hour data, and Tables 13-6 and 13-7 give information on 15-minute and 24-hour surface and subsurface data.

Table 13-4. Meteorological Variables Measured (or Calculated) Every 15 minutes at Height *z*

Level	z (m)	Wind							Atmospheric State					Precipitation				Radiative Energy Fluxes					Eddy Fluxes	
n		u	σ_u	θ	σ_θ	w	σ_w	u_*^2	T	p	h	T_d	q	r	s_d	s_f	l	$K\downarrow$	$K\uparrow$	$L\downarrow$	$L\uparrow$	Q^*	Q_h	Q_e
TA-6																								
4	92.0	x	x	x	x	x	x		x															
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x	x	x				x										x	x
0	1.2								x	x	x	x		x	x	x	x	x	x	x	x	x		
TA-41																								
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x		x															
0	1.2								x									x						
TA-49																								
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x		x															
0	1.2								x		x	x		x				x						
TA-53																								
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x		x															
0	1.2								x		x	x		x				x						
TA-54																								
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x	x	x				x										x	x
0	1.2								x	x	x	x		x				x	x	x	x	x		
PJMT																								
1	36.6	x	x	x	x				x															
0	2.0								x	x	x	x		x	x	x								
MDCN																								
1	10.0	x	x	x	x	x	x		x															
0	1.2								x									x						

Table 13-5. Meteorological Variables Measured (or Calculated) Every 24 hours at Height *z*

Level ***n***	**z (m)**	**Wind**			**Atmospheric State**						**Precipitation**			**Radiative Energy**					**Heat Energy**	
		$\bar{u}$	u_{mx} θ_{mx} t_{mx}	u_{mx1} θ_{mx1} t_{mx1}	T_{mx} t_{mx}	T_{mn} t_{mn}	p_{mx} p_{mn}	$\bar{h}$ h_{mx} h_{mn}	$\bar{T}_d$ T_{dmx} T_{dmn}	$\bar{q}$	$\hat{r}$	$\hat{s}_f$	$\hat{l}$	$\hat{K}\downarrow$	$\hat{K}\uparrow$	$\hat{L}\downarrow$	$\hat{L}\uparrow$	$\hat{Q}^*$	$\hat{Q}_h$	$\hat{Q}_e$
TA-6																				
4	92.0	x	x																	
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x						x									x	x
0	1.2				x	x	x	x	x		x	x	x	x	x	x	x	x		
TA-41																				
2	23.0	x	x																	
1	11.5	x	x	x																
0	1.2				x	x								x						
TA-49																				
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x																
0	1.2				x	x		x	x		x			x						
TA-53																				
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x																
0	1.2				x	x		x	x		x			x						
TA-54																				
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x						x									x	x
0	1.2				x	x	x	x	x		x			x	x	x	x	x		
PJMT																				
1	36.6	x	x	x																
0	2.0				x	x	x	x	x		x	x								
MDCN																				
1	10.0	x	x	x																
0	1.2				x	x								x						

Table 13-6. Surface and Subsurface Variables Measured (or Calculated) Every 15 minutes at Height or Depth *z*

z (m)	Q_g	χ_w	T_s	W_{10}	W_1
TA-6					
0.30				x	x
-0.08	x				
-0.02			x		
-0.06			x		
-0.04		x			
-0.10			x		
-0.03 to -0.18		x			
TA-54					
0.30					
-0.08	x				
-0.02			x		
-0.06			x		
-0.04		x			
-0.10			x		
-0.03 to -0.18		x			

Table 13-7. Surface and Subsurface Variables Measured (or Calculated) Every 24 hours at Height or Depth *z*

z (m)	$\hat{Q}_g$	$\overline{\chi}_w$
TA-6		
-0.08	x	
-0.02		
-0.06		
-0.04		x
-0.03 to -0.18		x
TA-54		
-0.08	x	
-0.02		
-0.06		
-0.04		x
-0.03 to -0.18		x

c. Sampling

The 15-minute sampling period recommended by the DOE “Environmental Regulatory Guide” is used throughout the network. This period is long enough to give good estimates of both mean and turbulence quantities when conditions are fairly steady, yet it is short enough to provide adequate temporal resolution during periods of change for emergency response modeling.

The time associated with each datum is the ending time in MST of the standard 15-minute sampling period; for example, hh15, hh30, hh45, and hh00. All maxima, minima, and other 24-hour summary values are based on the 0000–2400 MST period.

The sampling rate for most primary variables and their standard deviations is 0.33 Hz, or one sample every 3 seconds. This rate results in a 15-minute sample size of 300, which is large enough to estimate means to ±5%. The standard deviation of the vertical velocity is underestimated by 15% during the day and 25% during the night because of the propeller’s slow response. For the event-driven signals, such as precipitation and lightning, the 0.33-Hz sampling rate does not apply.

The sampling rate of the fuel moisture is one sample every minute for a total of 15 samples for every 15-minute period. This smaller sample rate is recommended by the manufacturer and is suitable because of the slow nature of change in the fuel moisture of a 10-hour fuel stick. The sampling rate for the subsurface measurements is one sample every 10 seconds.

Maxima and minima are generally based on data collected at the 0.33-Hz sampling rate. The exception is the 1-minute wind gust, which is based on non-overlapping 1-minute averages. The maximum instantaneous wind gust is actually a 1- to 2-second average gust because of the instrument’s limited response. Slow instrument response also affects the extremes of temperature, pressure, and relative humidity.

The covariances used to estimate the eddy fluxes of heat, moisture, and momentum are computed from data sampled at a 1-Hz rate, which results in a sample size of 900. Eddy flux data archived before 1998 were derived from vertical winds measured by propellers, and the slow response of the propellers caused an underestimation of the fluxes. Experiments suggest that using a propeller for flux measurement causes the sensible heat flux to be underestimated by 15%, the latent heat (moisture) flux to be underestimated by 10%, and the momentum flux to be underestimated by 30% (Stone et al., 1995).

2. Data Management

a. Description of the Data Management Component

The data management component of the program controls the processing of the meteorological data, from its measurement to its archiving and the automatic construction of graphics and tables. These end products are then made available to various applications and services, such as the program's software for hazardous release modeling (called MIDAS—Meteorological Information Dispersion Assessment System) or the program's website (called the Weather Machine).

The data management objectives are to (1) maintain a secure, high-quality data archive and (2) deliver data, statistical summaries, graphics, special data sets, and other weather products to a large customer base as efficiently as possible. A significant portion of the program's resources have been devoted to fulfilling these objectives, including a substantial investment in personnel, hardware and software, and maintenance contracts.

Standards for data management follow guidance when applicable, such as in the calculation of turbulence quantities (EPA 1987), wind vector quantities (EPA 1987), stability categories (EPA 1978), and the formatting of model input files (EPA 1987).

Improvements in the data management component during the mid 1990s have increased the program's visibility, improved accessibility to the data for customers, increased usage of the data, and increased the overall efficiency of the program. Significant changes include the establishment of a website (the Weather Machine) in 1993, the development of a local binary data archive and software to move data to and from this archive (1995), creating a common gateway interface (CGI) feature for the Weather Machine for distributing data (1996), and the addition of several graphics packages for such products as wind roses, annual summaries, and monthly summaries (1996 and 1997).

b. Hardware and Software

The program operates three Hewlett-Packard (HP) workstations, three x-terminals connected to the workstations, a host of Campbell Scientific, Inc. (CSI) data loggers, and accompanying peripherals such as printers, external disks, and additional IBM and Macintosh PCs. Figure 13-4 shows these hardware components and the associated linkages.

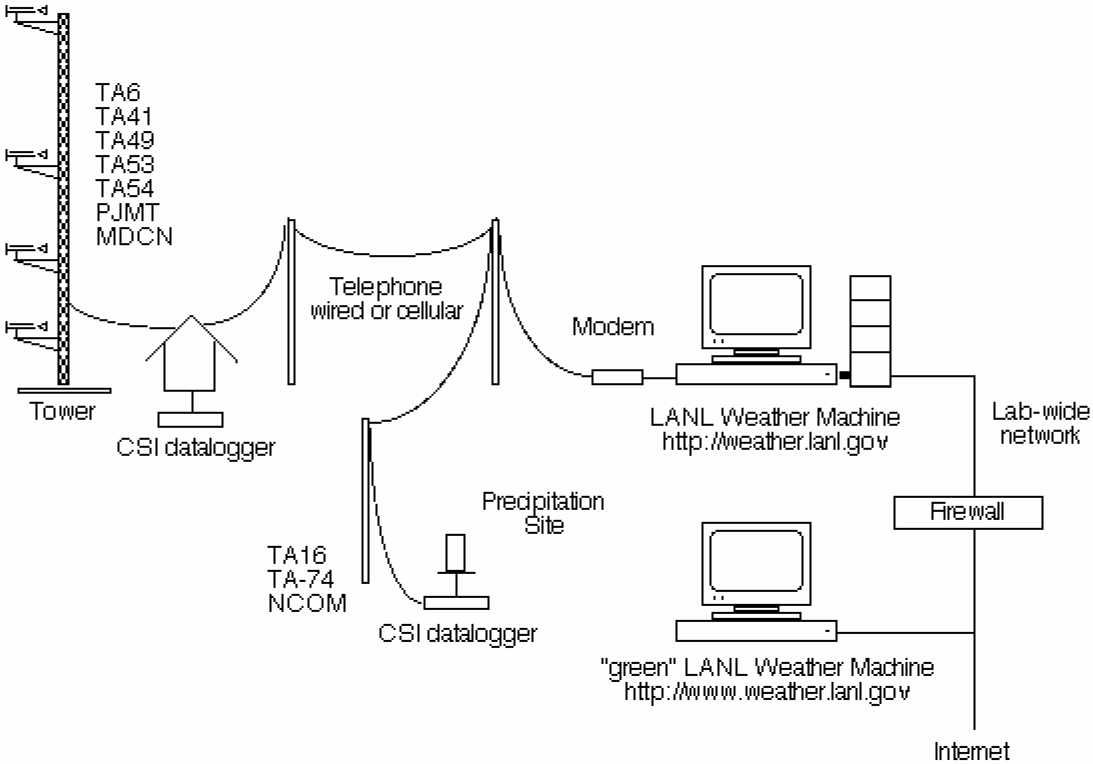

Figure 13-4. Main hardware components used in acquiring and processing meteorological data.

The program relies on several software packages, primarily in Hewlett-Packard's UNIX operating system, HP-UX (version 10.01). Below is a list of the software tools used by the program:

- **Cron** is a UNIX utility that runs all the automatic processes.
- **Shell scripts** consist of a series of UNIX commands. Shell scripts are run by cron and control all routine, periodic data processing by calling C language executables and PV-Wave executables.
- **C** language executables convert datalogger data to binary data, allow access to binary data, perform data requests from the web server, and construct model input data files.
- **PV-Wave** is a programming language designed for visual data analysis. PV-Wave generates all routine graphical displays for the Weather Machine and is used by the program staff to perform data analysis.

- **Perl** is a text processing language used in CGI applications. Perl scripts serve hypertext markup language (HTML) forms in Web browsers and pass information to and from clients. Perl is used by the program to manage raw data request forms and model input request forms on the Weather Machine, along with other functions requiring text processing.
- **Apache** is the web server software used to run the Weather Machine.
- **Campbell Scientific Datalogger programming language** is used by dataloggers to control sampling, perform signal conditioning, and carry out initial processing (such as the computation of means, variances, and daily totals).
- **PC208W** software communicates with the Campbell Scientific, Inc. data loggers. PC208W only runs in a PC environment, requiring the use of SoftWindows.
- **SoftWindows** is the UNIX software used to emulate a PC environment to allow PC208W to execute.

c. Routine Data Acquisition and Processing

In 1996 the binary data format replaced the 80-column textual format as the primary form of data archive. All routinely processed data are placed into binary formatted files for storage, and other special, non-routine data sets are also formatted into binary files when possible.

The data record for each station consists of a series of annual binary files and a 90-day circular binary file for the 15-minute data; similarly, the 24-hour data are stored in annual files and a 90-day circular file. Data in the circular files are checked weekly for quality and then are moved over to the annual files. Thus the annual files contain only data that have been thoroughly checked and edited. Both circular and archive files are accessible through the CGI interface on the Weather Machine or through the PV-Wave custom application programming interface (API).

Data acquisition and processing operations are performed at regular intervals on several different time cycles. Below is a simple outline of these operations. All operations in the outline are automated except for the weekly, monthly, and annual tasks, which are performed manually.

1. On a 15-minute cycle, cron
   - runs a script that invokes SoftWindows and PC208W, the data loggers are called (except Pajarito Mountain), and the latest data are transferred from the data loggers to the HP workstation;
   - runs a script that converts data logger files to UNIX files;
   - calls a C language executable that reads the UNIX files, compares the data with expected ranges, and writes the data to binary circular files (data values falling outside predetermined ranges are entered with a standard "bad" value indicator, usually denoted by the * symbol upon output);
   - runs scripts that run PV-Wave executables which read the binary circular files and update graphical and tabular summaries of current conditions; and
   - runs a script that runs a C language executable that uses the binary files to feed data to the Meteorological Information and Dispersion Assessment System (MIDAS) (see Section 4).

2. On an hourly cycle (from 0700–1500 MST only), cron performs the same operations as for the 15-minute cycle in calling the cellular phone at the Pajarito Mountain station. The Pajarito Mountain station is called hourly from 0700–1500 MST to reduce cellular phone charges, but

a special utility can be invoked to call the Pajarito Mountain station every 15 minutes during emergency situations.

3. On a 24-hour cycle, cron
   - calls a script that runs PV-Wave executables that generate tabular and graphical summaries for the previous day; and
   - runs a script that sends email to the program staff concerning the status of data collection and range checking for the previous day.

4. Weekly,
   - data collected during the previous week are reviewed;
   - the circular files are edited; and
   - edited circular file data are moved to their respective current annual files.

5. Monthly,
   - a PV-Wave executable is run to summarize the previous month's weather; and
   - a PV-Wave executable is run to update the daily and monthly extremes table.

6. In January, PV-Wave executables are run that construct an annual weather summary and wind rose plots for the previous year (for the Laboratory's Environmental Surveillance Report).

In addition to processing data from the local meteorological network, program software

- automatically retrieves meteorological data from other websites;
- analyzes the system status and log files;
- automatically handles raw data requests and model input data requests to the Weather Machine; and
- sends automatic email weather forecasts to a list of clients.

Figure 13-5 shows the locally constructed software components that control flow from the original raw data measurements to the final products. MDM.out, a C executable, controls flow to and from binary files and supports data requests to the Weather Machine. MS.out and STAR.out handle model input data requests. PV-Wave is used for producing routine summaries and graphics, as well as for special analyses.

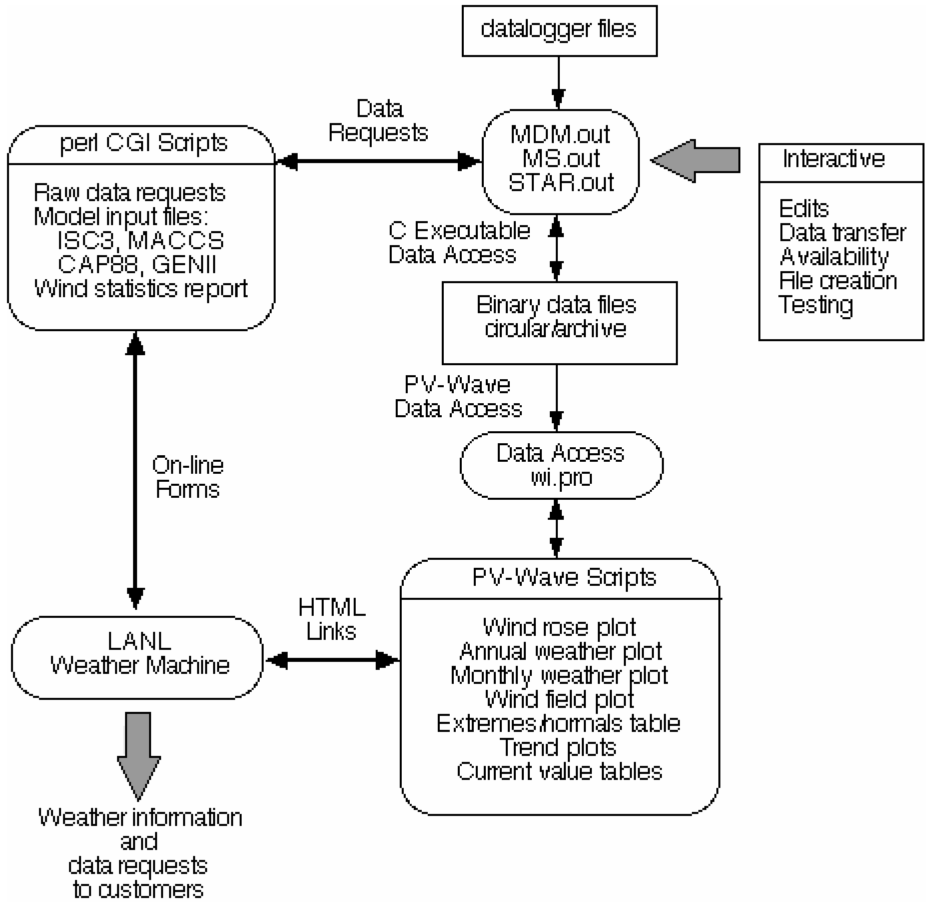

Figure 13-5. Main software components that control the flow of raw data from raw data files to the formatted products.

3. Data Analysis and Forecasting

Some program customers require more than access to raw meteorological data or standard summaries. Interpretation of raw data, computation of special quantities, or even measurement of special meteorological variables may sometimes be requested. The data analysis component of the program serves to fill this need.

Extensive analysis of the early tower data was conducted by Bowen in the mid-to-late 1980s, culminating in the document “Los Alamos Climatology” (Bowen 1990). Shortages in staffing led to a lull in analysis until the mid 1990s, when analysis again was feasible due to the addition of a staff member and improvements in data management. During this time many memorandums, reports, and draft reports were completed that aided in the understanding of the local meteorology of the Los Alamos area. A bibliography of local meteorological analysis studies can be found in a memorandum by Stone and Baars (1998).

Weather forecasting is another type of analysis performed by the program. Forecasts are used primarily in the winter when snow storms affect construction projects, road crew scheduling, school busing, and airport operations. Forecasts also support emergency response operations, explosives testing, and aerial photography campaigns. Because of limited resources for this activity, the program's policy is to make forecast information available on the Weather Machine. Area forecasts, or "zone forecasts," from the U.S. National Weather Service (NWS) are also automatically emailed up to three times a day, seven days a week, to a list of customers, including the Laboratory's Emergency Management and Response Group (S-8), Los Alamos County organizations, schools, and other requesting contractors. Only when snow storms threaten does program staff develop their own forecasts.

4. Modeling

One of the primary purposes of conducting meteorological monitoring at DOE sites is to maintain a plume modeling capability in support of emergency planning and response. For many years the program provided this service using simple, straight-line Gaussian plume models. These models were deemed inadequate because they did not account for the Laboratory's complex terrain, multiple facilities, and numerous hazardous materials. Furthermore, the models did not take advantage of real-time meteorological data or provide a map-based, plume contour plot.

In 1993, the program purchased MIDAS (Meteorological Information and Dispersion Assessment System) to improve hazardous release dispersion modeling capabilities and to bring the Laboratory into compliance with DOE Order 5500.3A (DOE 1992). The model, developed by ABS Consulting, is used to calculate air concentrations and human dosages of hazardous materials released to the atmosphere. The rationale for choosing MIDAS over other available models at the time is given in Stone and Dewart, 1992. In 2001, an entirely new version of MIDAS, called MIDAS-AT was purchased because it incorporates new "anti-terrorism" capabilities. MIDAS-AT runs on a PC and, in addition to many other new features, is capable of assessing chemical and biological weapons releases.

MIDAS is a segmented plume or "puff" model. The model releases a series of puffs to the atmosphere, with concentrations calculated according to a time-dependent release rate of the hazardous material under examination. The trajectory of each individual puff is calculated according to the real-time measured wind field, with updates in the winds being incorporated into the calculation every 15 minutes as new tower data are acquired. In this way, spatial and temporal variations in winds are taken into account by the model. The growth of the individual puff is controlled by atmospheric stability, which is based on measured standard deviation of wind direction fluctuations. MIDAS also uses locally measured precipitation for a washout algorithm and uses temperature and wind speed for modeling evaporation from a chemical spill and for modeling plume rise, which also requires standard deviation of wind direction.

The wind field is automatically constructed from 11.5 meter winds from the four mesa-top towers (TA-6, TA-49, TA-53, and TA-54) using a simple $1/r^2$ interpolation scheme. A stability-dependent power law relationship governs the extrapolation of wind speed to reference heights that are higher or lower than 11.5 meters, and wind direction is assumed not to change in the vertical.

The model is not prognostic in the sense that wind fields are forecast and used to predict the resulting effect on the plume location. Projections of plume location provided by MIDAS-AT are calculated by assuming persistence in the current wind field.

The dataset used to calculate a plume in an emergency situation can be constructed "on the fly" or it can be selected from approximately 280 pre-defined scenarios. When run "on the fly", MIDAS-AT prompts the user for necessary information including released substance, amount, duration, and location of release. In addition, weather information including wind speed, wind direction, standard deviation of wind direction, temperature, and precipitation rate are requested if these data are not collected automatically. MIDAS-AT prompts the user for other additional information such as release height, release direction, pressure of released substance, and explosive equivalence of release (in kilograms of TNT). In many cases, optional sample responses are provided, including "I don't know".

In addition to running MIDAS-AT "on the fly", the user can select from predefined scenarios that were originally created for all medium- and high-risk facilities. This method of running MIDAS is typically faster and simpler, as most of the information has already been specified. When run this way, only a few additional pieces of information need to be defined, including the start time of the release, which meteorological tower data to include, and whether to use the plume segment (fast) or the complex terrain (slow) model. In all cases, MIDAS stores information about the materials themselves, as well as building information for which scenarios exist.

MIDAS is relatively easy to use, even for those with little training on the model. Once the user has input all of the information that MIDAS-AT requires, a plume calculation is produced in about 30 seconds (plume segment model) or 2 to 5 minutes (complex terrain model). Interpretation of the results and the use of the advanced capabilities of the model require an experienced user, however. Determining how realistic results are in a meteorological sense requires a strong background in meteorology. Understanding the consequences of selecting varying input parameters also requires more advanced training in the use of the model.

Output from MIDAS includes a variety of text and map products. The most important MIDAS output is probably the graphic showing the estimated plume superimposed on a Laboratory map. The plume shows the region where the concentration, dose, or dose rate (the user can freely move between different output screens) exceeds the relevant emergency response thresholds, such as ERPG (emergency response planning guidelines) or IDLH (immediately dangerous to life and health). A zoom feature and a concentration-at-a-point feature are included with this map.

Figure 13-6 shows an example of plume-on-map output from MIDAS-AT. In this example a hypothetical criticality release from TA-18 is shown. Many radiological scenarios are set up in MIDAS–AT such that the released substance is treated as being equivalent to Pu-239, which is a fairly conservative treatment since Pu-239 has a relatively high dose conversion factor (rem/Curie). The three contours shown (red, orange, and pink) denote areas where the dose is projected to exceed 0.15 rem approximately 5, 15, 30, and 60 minutes from the present time, 8:15 pm, which is 1 ½ hours after the time of release.

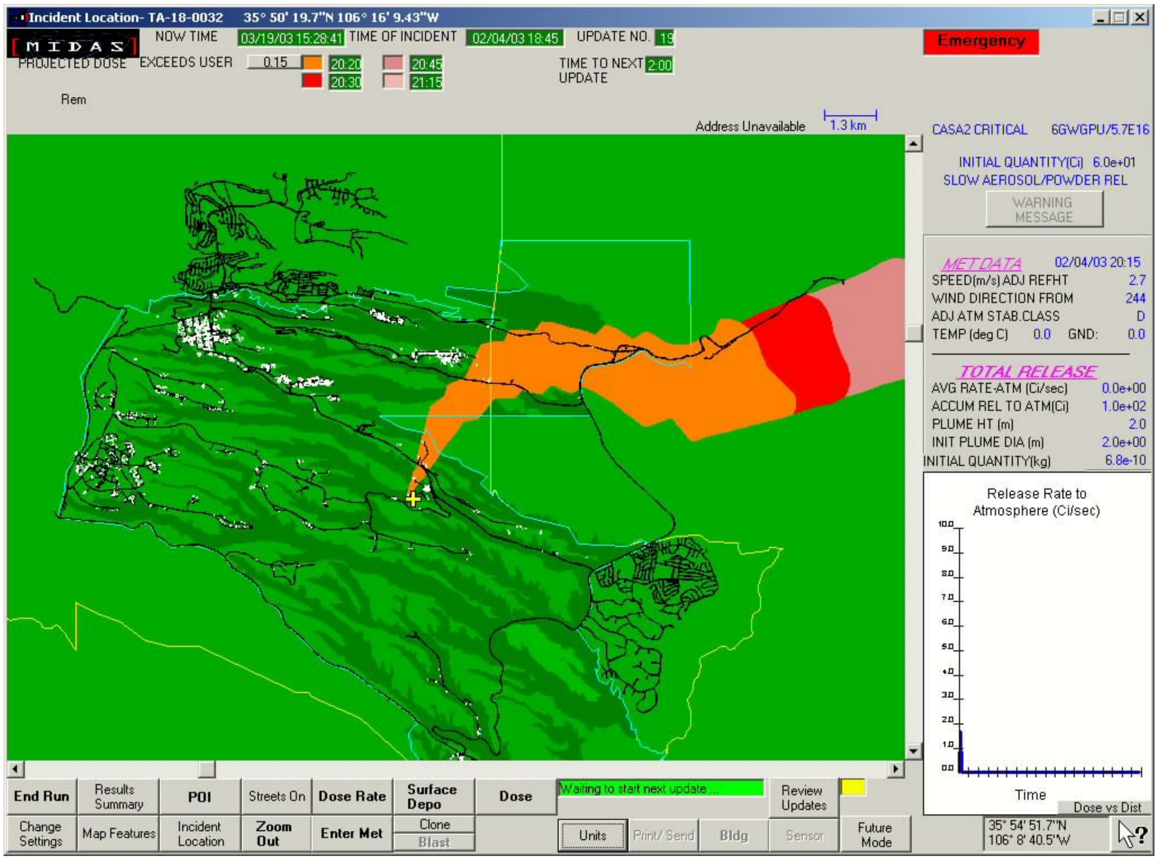

Figure 13-6. Example MIDAS output for hypothetical criticality event at TA-18.

Limitations and uncertainties with MIDAS are typical of those associated with a model of this type. For instance, projections are based on the persistence of the wind field, so when winds are light and variable, there are large uncertainties in the results. Figure 13-6, for example, shows a plume that curves from the time of release up to the present time (1 ½ hours after release). But the projections into the future, which are based on the presumption of persistence of weather-related quantities such as wind direction, show straight-line plume travel. Also, flows in the canyons are not accounted for and azimuthal shear in the vertical is not taken into account.

Extensive studies have been performed on models similar to MIDAS. One such study for surface releases in complex terrain was performed in 1980 and 1981 during the atmospheric studies in complex terrain (ASCOT) study (Dickerson and Gudiksen, 1984). When comparing the model results with actual measurements, the study found that model-predicted concentrations were within a factor of five 50% of the time and within a factor of 10 about 60% of the time. In our comparisons of MIDAS-AT to straight-line Gaussian plume concentration calculations, MIDAS-AT almost always gives relatively conservative projections, typically predicting dose and concentration calculations that exceed predictions of the simple Gaussian method by less than a factor of ten.

When appropriate, program meteorologists also use the EPIcode, Archie, and HOTSPOT models. These models are straight-line Gaussian plume models, and they do not take advantage of the real-time measured wind field.

5. Data Accessibility

The program's website—the Weather Machine (http://weather.lanl.gov)—was established in 1993 as a means of distributing the tables and plots already in use for quality assurance and for emergency response applications. The Weather Machine has now developed into a useful tool for servicing routine data requests, providing information to the local weather-curious, promoting positive public relations, and making an extensive meteorological dataset more accessible.

The Weather Machine provides a variety of meteorological data, including local weather information, weather forecast products, regional and national weather information, and local climatological data. On-line documentation is accessible, making the Weather Machine a stand-alone meteorological service.

Also included in the Weather Machine are data request forms that provide access to the raw data archive and model input files for some of the frequently used atmospheric dispersion and dose assessment models (ISC3, MACCS, CAP88, and GENII). The actual data request forms are in an HTML format, and the data can be downloaded directly into a spreadsheet. The request forms are constructed depending on data availability and user-specified information.

The users of the Weather Machine consist of internal Laboratory employees, DOE laboratories, universities, and the public sector. Internal lab users are able to access the site's contents freely; however, the introduction of a firewall in 2000 between the Lab-wide network and publicly accessible internet has restricted public availability of the Weather Machine. As a result, public data requests are typically serviced by phone and email communication.

6. Program Changes Since the 1998 EMP

a. Measurements

- MDCN tower was installed on December, 2002.
- A datalogger was set up to create a data set for the Weather Information Management System (WIMS).
- A new sodar has been purchased and installed to replace the TA-6 sodar damaged in the May, 2000 Cerro Grande fire. After calibration and testing, the new sodar will be made operational.
- New R.M.Young wind instruments (models 05701-RE and 05305-AQ) were installed during the 2002-2003 in-house calibration cycle. This change was implemented because the prior instruments were reaching obsolescence because of diminishing parts availability.

b. Data Management

- The HP-715 UNIX workstation was installed in the emergency operations center (EOC) and configured as a backup for the primary MIDAS workstation.
- Data access was improved through the creation of the program a PV-Wave interface to all the program's data.

c. Data Analysis and Forecasting

- The program supported and participated in studies of local and regional winds in collaboration with the Laboratory's Atmospheric and Climatic Sciences Group (EES-8). The studies included analyses of canyon flows and the relationship between the near-surface wind over the Pajarito Plateau and winds at the regional scale (report in progress).
- Analysis of the sodar's performance was undertaken.

d. Modeling

- MIDAS-AT has been installed in the Emergency Operations Center (EOC).
- Several MIDAS-AT scenario updates were conducted.
- The MM5 mesoscale model has been installed and produces a 24-hour weather forecast once per day.

e. Data Accessibility

- The LANL Weather Machine has been improved by adding lightning data and snow depth data at TA-6.

f. Quality Assurance

- The Quality Assurance Project Plan was updated in April 2003.

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